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Determination of Earthquake Effects on Sandy Soils for the City of Eskisehir, Turkey

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Abstract Dynamic soil behavior has to be known very well to consider safe and economical precautions against earthquake effects. This paper deals with modelling study to predict deformations under earthquake effect for city of Eskisehir, Turkey. Various deformation types can occur due to the earthquake for different type of soil. In this study, soil deformations are found under possible earthquake by using Plaxis 2D software. Soil types are chosen as silty sand and loose sand due to most common soil types in Eskisehir. Results are presented and suggestions are given to minimize soil deformations under earthquake effects. Deformations change depends on the local soil types. Therefore, precautions should be determined according to local soil conditions.

***Index Terms*—earthquake, Plaxis 2D, sandy soil, silty sands, soil deformation,**

I. Introduction

Geotechnical earthquake engineering is a sub-discipline of the soil mechanics and foundation engineering division. Dynamic soil behavior has to be known very well to consider safe and economical precautions against earthquake effects such as stability failure, deformations and etc. Earthquake is defined as ground shaking due to the sudden breakages in the ground mantle [1]. Earthquake is also high energy discharge and creates large ground motions and dynamic loads.

In the past experiences, earthquake-related damages were as loss of human lives and total collapse of structures or large deformations. Soil deformations induced earthquake are classified as surface rupture, regional subsidence, slope movements, volumetric compression, liquefaction, settlement and bearing capacity failures, horizontal expansions and sand volcanos [2]. Especially, bearing capacity failure, high settlement and liquefaction are mostly seen soil deformations. Bearing capacity failures can occur due to the shear strength loss. Liquefaction is explained as decreasing the effective stress of the sub-soil with increasing excess pore water pressure and causes either tilting or punching of the superstructure.

The dynamic response of the soil can be determined by laboratory, field and model tests. Main laboratory dynamic tests are resonant column test, cyclic triaxial test, cyclic simple shear test and bender element test. Field tests are standard penetration test (SPT), cross-hole test, down-hole test, seismic reflection test and other seismic tests. Shaking table and centrifuge tests are known as model tests [1]. On the other hand, many software are started using to estimate dynamic behavior of the soil during the earthquake, nowadays. Development of the computer technology gives opportunities to easy and fast analyzes. But modelling has great influence on the realistic results.

There are many published studies in the literature to determine the soil behavior during the earthquake. Naeini and Baziar investigated layered soil behavior by using dynamic triaxial test [3]. Yang and Elgamal studied relationship between liquefaction and permeability by numerical modelling [4]. Hwang et all. showed that liquefaction is related with topography, stratigraphy and soil structure [5]. Lancelot et all. found that deformations are affected from excess pore water pressures [6]. Kokusha et all. analyzed deformations during the dynamic loading by using dynamic shear test [7]. Okada et all. determined the shear deformations of the sandy soils by performing undrained dynamic tests [8]. Zhou and Chen presented that strains are increased with effective stress loss, saturation and rigidity disturbance [9]. Yunmin et all. researched the liquefaction potential of the sandy soils and deformations

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induced earthquake waves [10]. Thevanayagam and Martin studied about decreasing the liquefaction deformations and suggested compaction for loose soils [11]. Yang et all. investigated the liquefaction potential of local soils and their behavior under earthquake loads [12]. Adalier and Elgamal compared the performance of soil improvement methods against earthquakes [13]. Osinov modeled the soil deformations by using differential methods and gave a new approach [14]. Chang presented the relationship between soil deformations and ground water level under the earthquake loading [15].

In this study, soil deformations are presented for city of Eskisehir, Turkey under possible earthquake effects. Various models are created and analyzed by using Plaxis 2D dynamic module. At the end of the study, the results are discussed and suggestions are given.

II. Method

In this study, Plaxis 2D software is used for modelling. Plaxis is a commercially available finite element program and used commonly in geotechnical engineering for the deformation and stability analysis. The software can make numerical solutions based on the finite element method [16]. The software can solve the problems with using either 2D or 3D analysis.

Plaxis 2D dynamic module can perform dynamic analysis by using vibration models with linear elastic theory [16]. In the input step; during the creation of geometry, dynamic loads are placed and in the calculation step; after static loading determination if it is exist, dynamic loading can be created by two ways. One of them is entering the data such as amplitude, frequency etc. in harmonic loading segment and the other way is loading a recorded earthquake data file with file extension like ".smc" [1]. After the calculation deformations, velocity and acceleration graphs can be seen in the output step. An example screen of the software is given in Fig. 1.

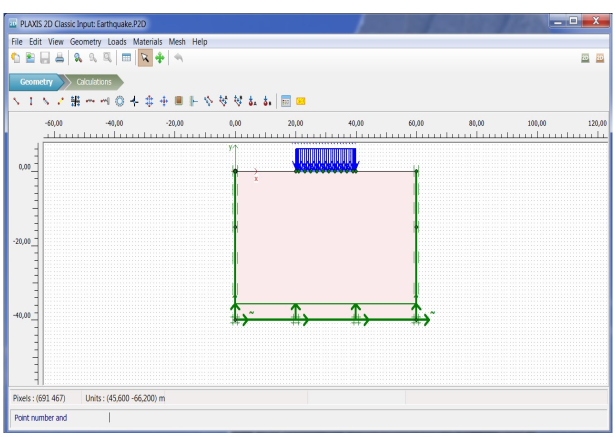

Fig. 1. Example screen of the Plaxis 2D

A. Study Details

City of Eskisehir is located in the second degree earthquake zone at the Earthquake Zoning Map of Turkey. On the other hand, two fault zone can affect the city of Eskisehir according to the data files taken from Republic of Turkey Prime Ministry Disaster and Emergency Management Presidency official web site. One of them is North Anatolian fault and far from about 80 km. and the last earthquake movement was in 1999 (Mw=7.4). The other one is Eskisehir fault and the greatest earthquake record was Mw=6.4 in 1956 [17].

Earthquake data file must have ".smc" extension to run models at the Plaxis. Unfortunately, there is no record with these extensions about 1999 and 1956 Earthquakes. Therefore, two earthquake data files are chosen due to the similarities of fault mechanisms and energy discharges. The strong ground motion records are taken from United States Geological Survey. Some date about the earthquake is given in Table 1.

TABLE I
EARTHQUAKE DATE

Earthquake Properties	Earthquake-1	Earthquake-2
Moment Magnitude	6.0	7.1
Epicentral Distance	63,20 km	132,90 km
Date	15.10.2006	15.06.2005
Location	Hawaii	California

B. Material Properties

Soil properties are taken from literature and previous soil exploration reports. Especially silty sand and loose sands are mostly seen soil types for the working area. Ground water level is generally high (about at -3.00 meters depth) so all soil profiles are considered fully saturated in the models. Some soil parameters are given in Table 2.

TABLE II
SOME SOIL PROPERTIES

Soil Properties	Silty Sand	Loose Sand
Material Type	Mohr-Coulomb	Mohr-Coulomb
Saturated Unit Weight	18.50 kN/m^3	19.50 kN/m^3
Poisson Ratio	0.3	0.3
Modulus of Elasticity	10000 kN/m^2	15000 kN/m^2
Cohesion	1,0 kN/m^2	0,1 kN/m^2
Internal Friction Angle	16°	26°

III. Model Study

Four models are created due to the mostly seen building groups in Eskisehir. Generally, 4 or 5 story buildings having can be seen in the city of Eskisehir. The foundation type is assumed to be mat foundation with the depth of -2.00 meters in the models.

A. Model-1

For the first model, a silty sand soil profile and 4 strorey building are considered and analyzed with using two earthquake effects. The model screen is given in Figure 2.

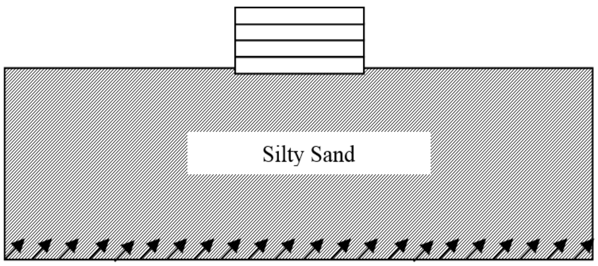

Fig. 2. Example screen of model-1

B. Model-2

For the second model, a silty sand soil profile and 5 strorey building are considered and analyzed with using two earthquake effects. The model screen is given in Figure 3.

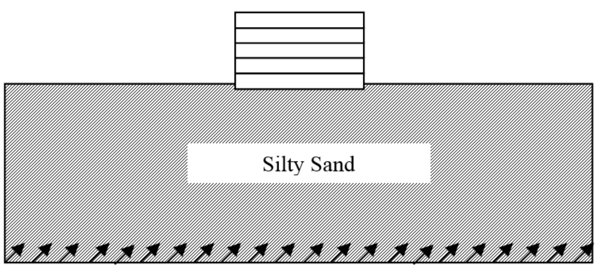

Fig. 3. Example screen of model-2

C. Model-3

For the third model, a loose sand soil profile and 4 strorey building are considered and analyzed with using two earthquake effects. The model screen is given in Figure 4.

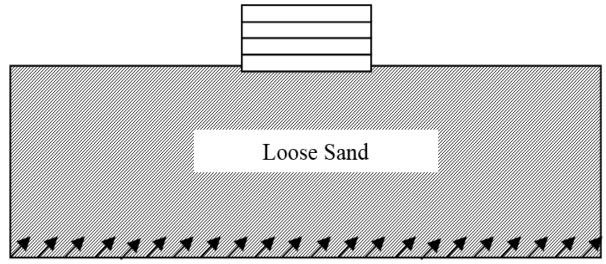

Fig. 4. Example screen of model-3

D. Model-4

For the fourth model, a loose sand soil profile and 5 strorey building are considered and analyzed with using two earthquake effects. The model screen is given in Figure 5.

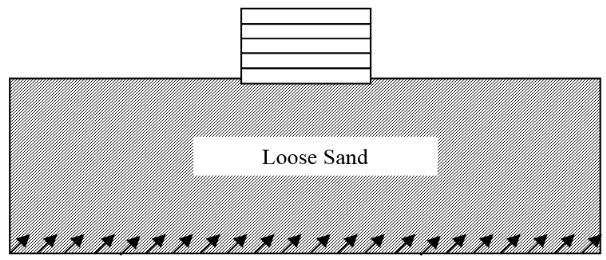

Fig. 5. Example screen of model-4

IV. RESULTS

In this study, Plaxis 2D dynamic module is performed for the model calculations. Deformations are found and given in Figure 6.

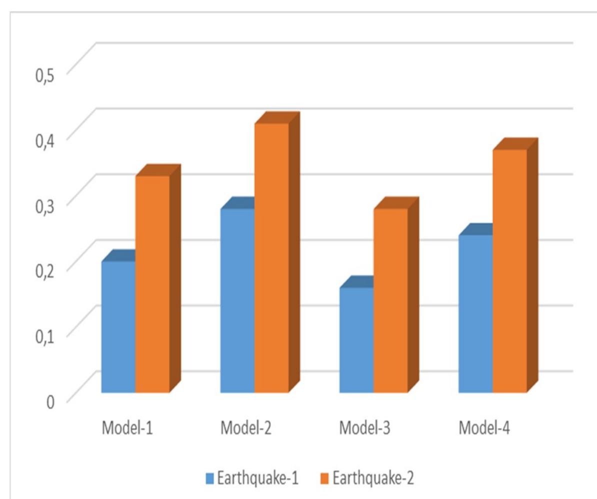

Fig. 6. Model results

The results of the analyses show that; deformation increases with magnitude of earthquakes. It is known that dynamic loads create excess pore water pressures and deformations. It ends with strength loss and bearing capacity failures Deformations in silty sand are higher from that of loose sand. Deformations and excess pore water pressures are occurred under earthquake loads for both saturated loose sands and sand silty sands. Effective pressures can easily equal to zero in the case of silty sands with lower plasticity and this causes high deformations. Water can easily drain due to the permeability and drainage conditions in the loose sands but lower plasticity silts can block and cause bearing capacity failures, non-uniform settlements and tilting on the structures [18].

V. Conclusion

Earthquake occurs suddenly and causes deformations. Structural damages can be occurred by these deformations. In this study, modeling studies of soil deformations under earthquake effects are presented. Results show that, earthquake loads can create different deformations due to local soil conditions and upper structure loads. And also this condition is called site-effect in the literature [19]. It can be seen that soil improvement techniques are needed to prevent deformations induced by earthquakes. On the other hand, realistic precautions need a database of past earthquake characteristics and local soil properties. Dynamic laboratory tests and in-situ tests should be performed to determine dynamic properties of soils. Soil improvement should be chosen according to the soil type and after improvement, quality control tests should be done in the field. This study is performed for specific soil properties and assumption of upper structures having enough strength.

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